

A NEW IPCC TIER 4 SITE-SPECIFIC MODEL FOR LANDFILL METHANE EMISSIONS INCLUSIVE OF SEASONAL METHANE OXIDATION



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Sixth Annual – 2009
Climate Change Symposium

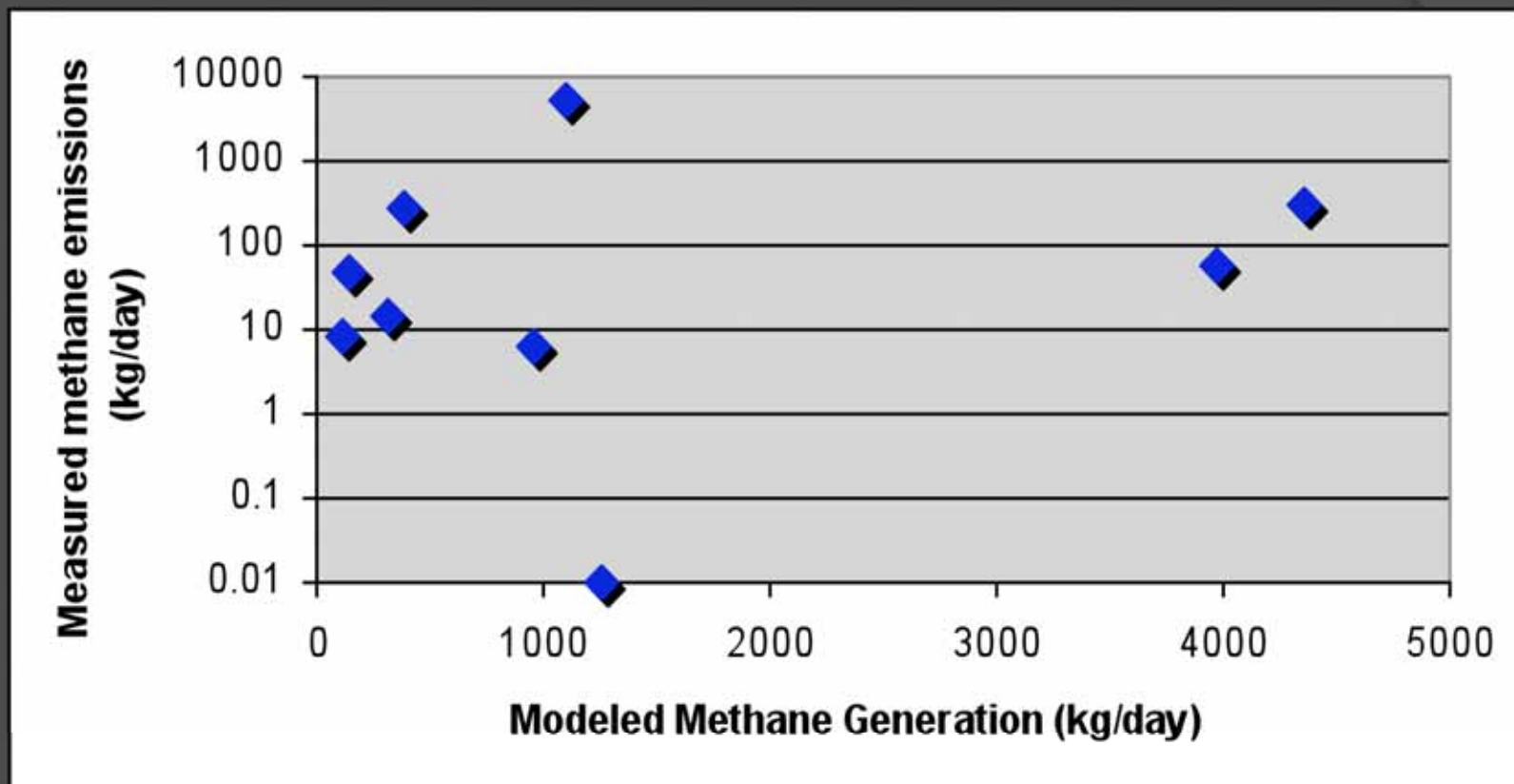
*The Future Is Now: Climate Change Mitigation,
Impacts, and Adaptation Research*



Why develop a new GHG inventory method for landfill methane emissions ?

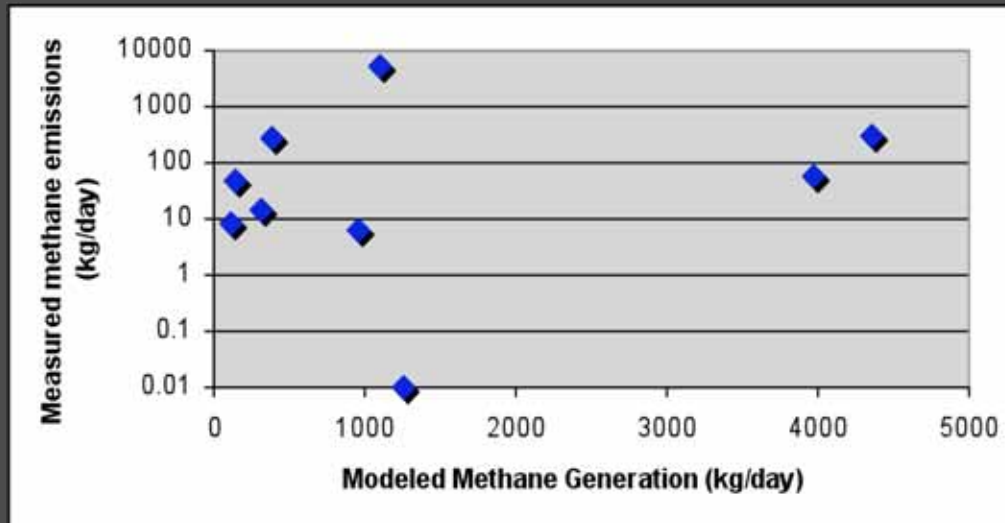
- Historical reliance on theoretical methane generation models for GHG inventory methods

Modeled landfill methane generation is not a very good predictor for landfill methane emissions...

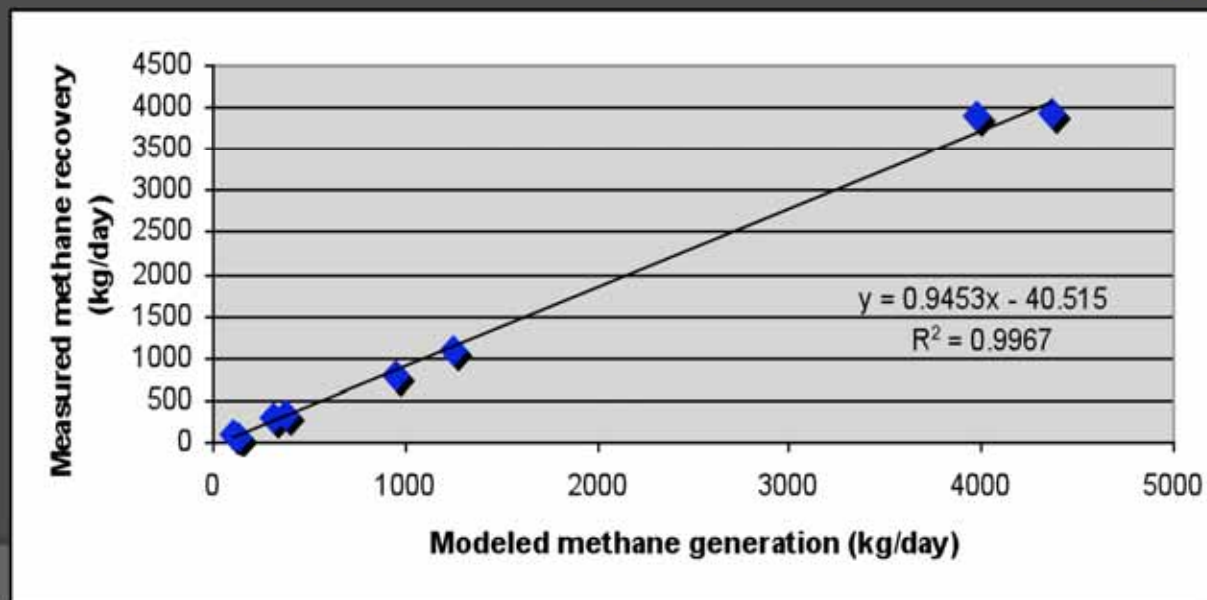


Data from a methane mass balance study at 7 different cells at three different French sites (Spokas et al., 2006)

Modeled landfill methane generation is not a very good predictor for landfill methane emissions...



However, the modeled generation is a good predictor for landfill methane recovery



Why develop a new GHG inventory method for landfill methane emissions ?

- Historical reliance on theoretical methane generation models for GHG inventory methods
- Recent field studies in several countries over the last 12 years
Improved understanding of process dynamics/mechanisms
- Increased regulatory and market interest in improved methodologies
 - Especially in California (GHG inventory; AB 32; CCAR)
- IPCC guidelines includes site specific model development (Tier 4)

Intergovernmental Panel on Climate Change (IPCC)
National Inventory Guidelines for Landfill Methane Emissions

1996

Tier 1: Mass Balance

Simplified carbon (C) mass balance
independent of time factor

Tier 2: FOD ("First Order Decay")

First order kinetic model
based on methane generation
potential (L_0) and kinetic constant (k).

New
Higher
Tier
Methods

THIS STUDY →

2006

Tier 1: FOD based on IPCC
defaults for specified
waste fractions:

Tier 1a: multicomponent FOD based on
waste composition

Tier 1b: multicomponent FOD based on
type of disposal site.

Tier 2: FOD based on country
specific model.

Tier 3: Use of "representative" whole
landfill field measurements.

Scales up field measurements to
national level.

Tier 4: Use of more complex site-
specific methods with results summed for
total national emissions.

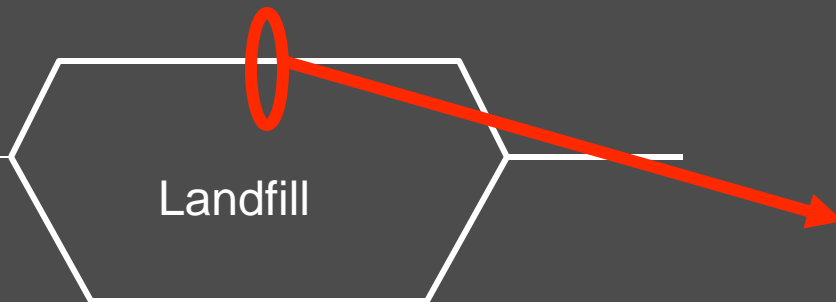
Project Goal

- Develop an improved GHG inventory methodology for landfill methane emissions in California based on a field-validated emissions model inclusive of seasonal methane oxidation

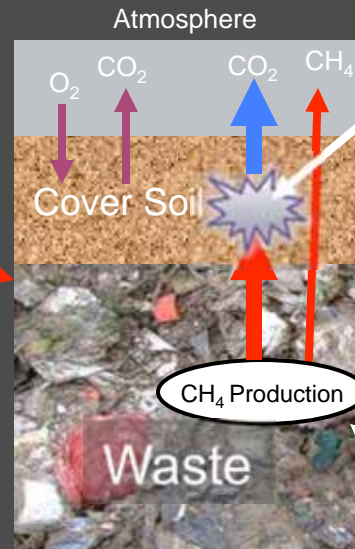
Primary consideration:

Balancing science-based methods with an appropriate level of detail for a regional GHG inventory

Closer look at soil methane oxidation



A very important consideration is methane oxidation in landfill cover soils => Reduction of landfill methane emissions by aerobic methanotrophic microorganisms:



CH₄ Oxidation

Methanotrophic oxidation:
[aerobic] methane consumption in cover soils

Dependent on:

- Temperature
 - Soil moisture
 - Oxygen presence
- } Climate

Methanogenesis:
[anaerobic] methane production in waste (gas generation models)



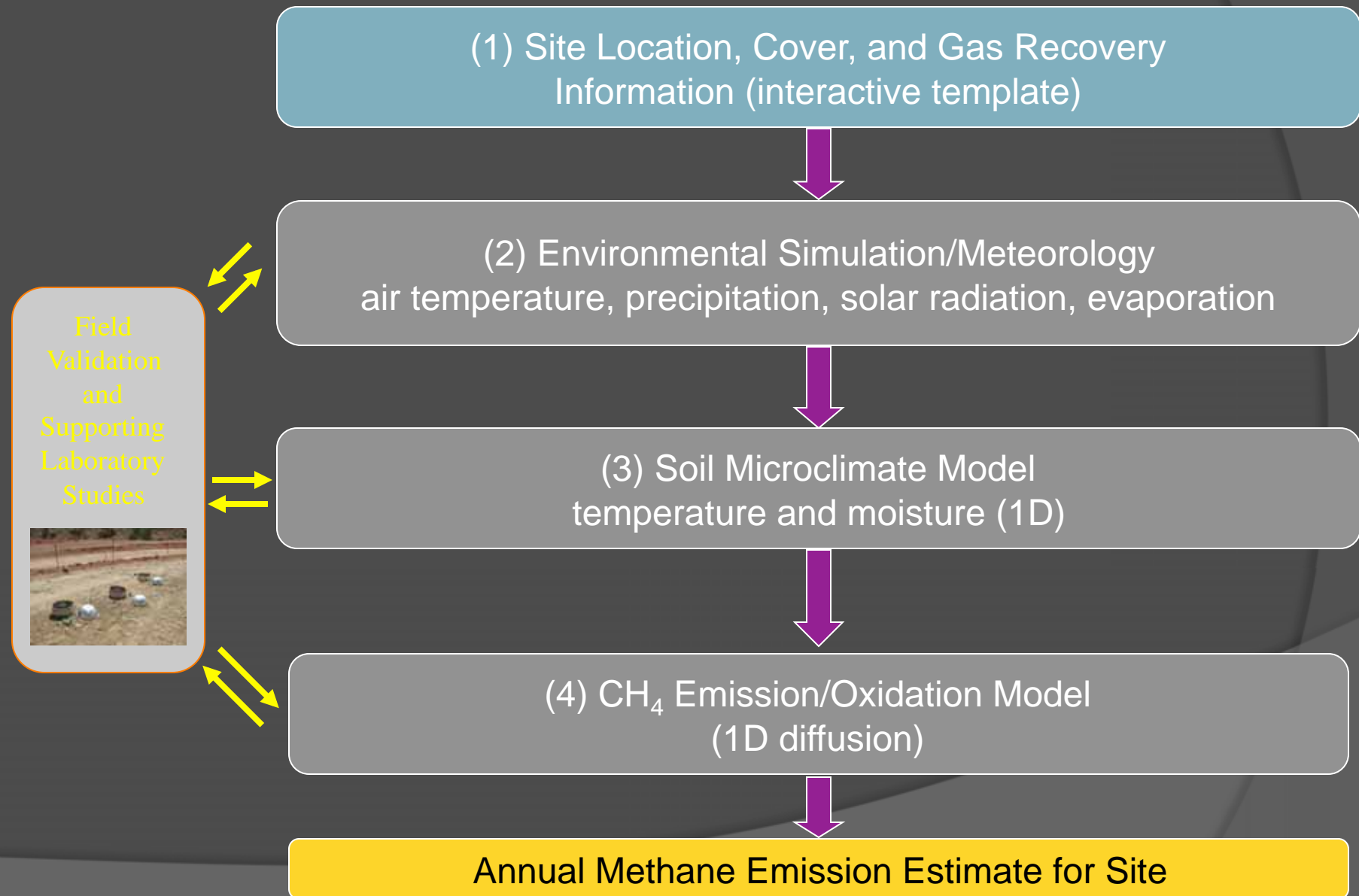
- Balancing the methane oxidation capacity of cover soils vs. methane transport to and through the cover
- Current inventory methodologies allow either 10% or zero methane oxidation
(10% based on Czepiel et al., 1996 for Nashua, NH landfill)
However, recent studies have indicated that this percentage is higher (Chanton et al., 2009)
- Previous studies have observed that soil matric potential explains 53–87% of the temporal variation in CH₄ oxidation (Borken et al., 2003).

Creating a New Tier 4 GHG Inventory Methodology for California

- ⦿ Move focus to CH₄ EMISSIONS rather than CH₄ GENERATION
- ⦿ Use of site-specific data for model implementation
 - Site location used to predict annual patterns for air temperature, precipitation and solar radiation
 - Coverage areas and characteristics of daily, intermediate, and final covers
 - Model currently handles up to 10 different cover types
 - Maximum depth of cover is 100 inches
 - 12 USDA soil texture classes as well as 11 non-soil categories (sludge, wood chips, tires, etc.)
 - Presence or absence of gas recovery system
- ⦿ Entry of site specific concentration gradients or model defaults

Java Model Overview

Landfill Methane Inventory Model – LMIM



LMIM

LMIM Version 3.7

Menu

Site Information

Site name:

SWIS number:

County:

Site Latitude:

Site Longitude:

Site footprint (acres)

IPCC Options

☐ Run IPCC model for comparison

Opening Year

Closing Year

Waste in place (tons)

Location Map

Lat: 37.89 Long: -124.06

Update Lat. & Lon. from map

Back

Next

Please select a site.

Site Info

Site Properties

Waste
Information

Cover Editor

Weather
Simulator

LMIM

LMIM Version 3.7

Menu

Site Information

Site name: Search

SWIS number:

County:

Site Latitude:

Site Longitude:

Site footprint

IPCC Options

☐ Run IPC

Waste in place (tons)

Select desired site:

- MONTEREY REGIONAL WST MGMT DST/MARINA LF
- MARY BEZAYIFF
- MCNAMARA & PEEPE WOOD WASTE DS
- MIRAMAR GREENERY
- MIRMAR WHOLESALE NURSERY
- MONTEREY REGIONAL WST MGMT DST/MARINA LF
- NILAND MARINA SITE
- NORTH MIRAMAR LANDFILL
- OLD SAN MARCOS LANDFILL

Location Map

Lat: 41.14 Long: -115.65

Update Lat. & Lon. from map

Back Next

Please select a site.

Site Info

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LMIM Version 3.7

Menu

Site Information

Site name:

SWIS number:

County: Monterey

Site Latitude:

Site Longitude:

Site footprint (acres)

IPCC Options

☐ Run IPCC model for comparison

Opening Year

Closing Year

Waste in place (tons)

Location Map

Lat: 32.84 Long: -123.19

Please select a site. Site Info

Site Properties

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LMIM Version 3.7

Waste Characterization:

☒ Use characterization from statewide study: ☐ Enter custom waste characterization

Custom Characterization:

Mass percent in waste stream

Paper waste:	22.61
Glass:	2.44
Metal:	7.3
Electronics:	0.99
Organic waste:	28.29
Plastic:	13.4
Construction waste:	18.57
House Hazard waste:	0.17
Special waste:	5.04
Mixed Residue:	1.17

Filling History:

Year	Amount of Waste(tons)
1955	132327
1956	132327
1957	132327
1958	132327
1959	132327
1960	132327
1961	132327
1962	132327
1963	132327
1964	132327
1965	132327
1966	132327
1967	132327
1968	132327

☐ Create new blank table

Waste Info

Site Properties

Waste
Information

Cover Editor

Weather
Simulator


LMIM

LMIM Version 3.7

Cover 1 Cover 2 Cover 3


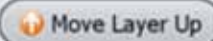

Cover Details:


Cover Type: ☒ Daily ☐ Intermediate ☐ Final


Coverage %  5% Cover age: Under 1 year old


Cover Make-up:


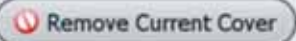
Layer(1 = surface)	Cover Material	Thickness(in.)
1	CLAY	12
	LOAMY SAND	
	SAND	
	Alternative Daily Cover - Wood Chips	
	Alternative Daily Cover - Compost Materials	
	Alternative Daily Cover - Sludge	
	Alternative Daily Cover - Chipped Tires	
	Alternative Daily Cover - Tarp	
	Alternative Daily Cover - Ash	

 Add Layer  Move Layer Up  Move Layer Down



Pre-defined Covers ->  None

☐ Gas Recovery  0%

☐ Vegetation Present  0%

 Add New Cover  Remove Current Cover

100% of site covered

 Back  Next

Cover Details

Site Properties

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Information

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LMIM Version 3.7

Menu

Cover 1 Cover 2 Cover 3



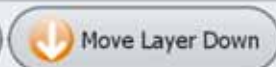

Cover Details:

Cover Type: ☐ Daily ☐ Intermediate ☒ Final


Coverage %  45% Cover age: Under 1 year old ▼


Cover Make-up:



Layer(1 = surface)	Cover Material	Thickness(in.)
1	LOAM	12
2	CLAY	12
3	SILTY CLAY LOAM	24

 Add Layer  Move Layer Up  Move Layer Down  Remove Selected Layer

Pre-defined Covers -> CCR Title 27 Design ▼

☒ Gas Recovery  99%

☒ Vegetation Present  50%

 Add New Cover  Remove Current Cover

100% of site covered

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Cover Details

Site Properties

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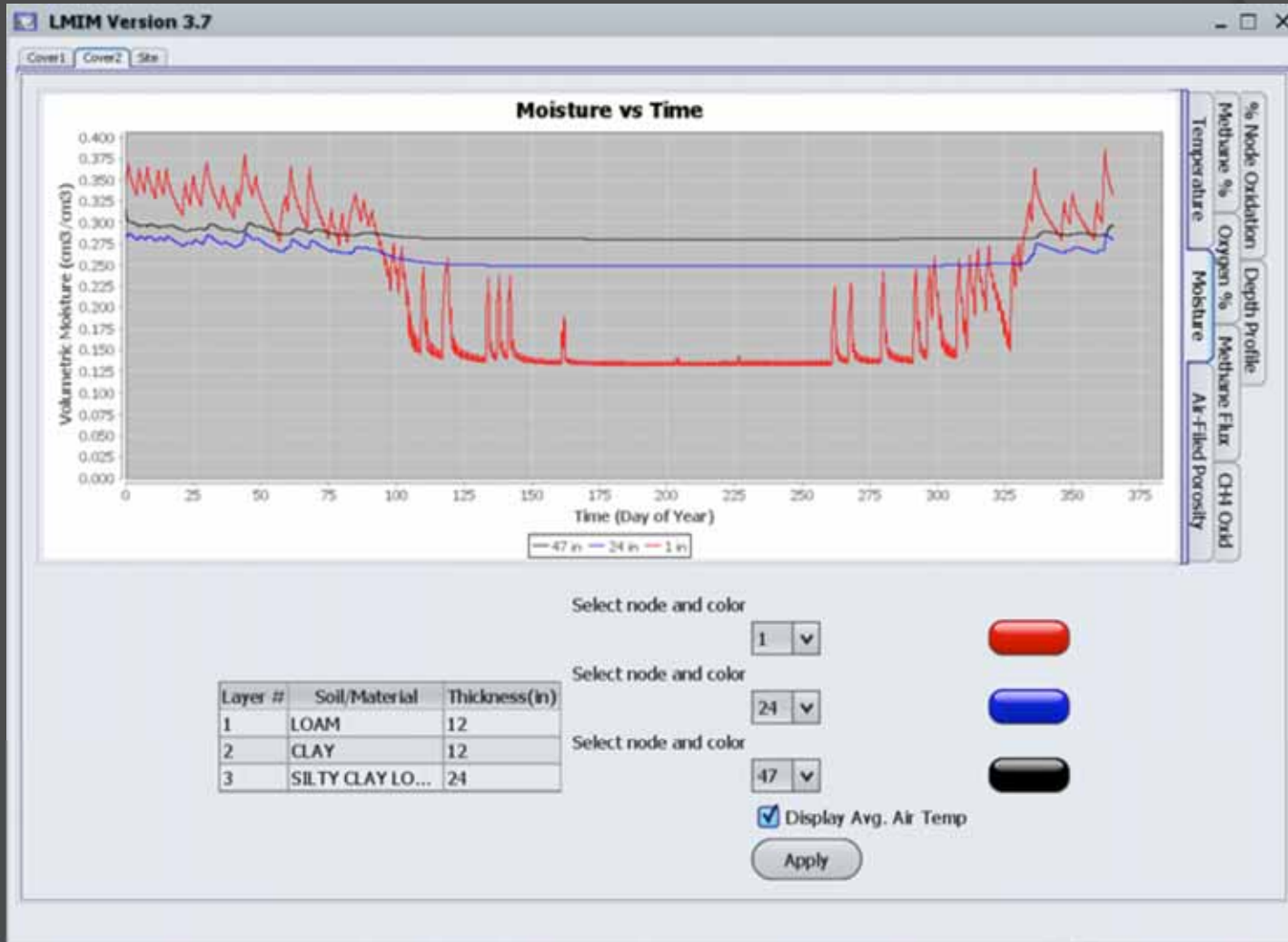
Site Properties

Waste
Information

Cover Editor

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Simulator

LMIM



Site Properties

Waste
Information

Cover Editor

Weather
Simulator

Model Output

Field/Laboratory Validation of Method

- **Field validation over 2 annual cycles at:**
 - coastal Marina LF (Monterey)
 - semi-arid Scholl Canyon LF (LA County)
- **Additional field validation using recent WMX data at**
 - Lancaster Landfill (Desert → Mojave)
 - Tri-Cities (Bay Area → Fremont/San Francisco Bay area)
 - Kirby Canyon (San Jose)

Field Validation

- Process level studies of methane emission rates ($\text{mg CH}_4/\text{m}^2/\text{day}$) using static closed chambers at Marina and Scholl Canyon (855 fluxes)
- Stable carbon isotopic method of Chanton and Liptay (2000) for determination of fractional methane oxidation.
- Supporting data for each flux:
 - 5cm soil moisture (TDR), soil gas concentrations, soil temperature (RTD), GPS location, air temperature, continuous chamber temperatures, and continuous water vapor (in chamber)
- Other supporting field studies/data:
 - continuous sub-surface CO_2 & pressure monitoring
 - Differential pressure in chamber
 - CO_2 & N_2O flux data



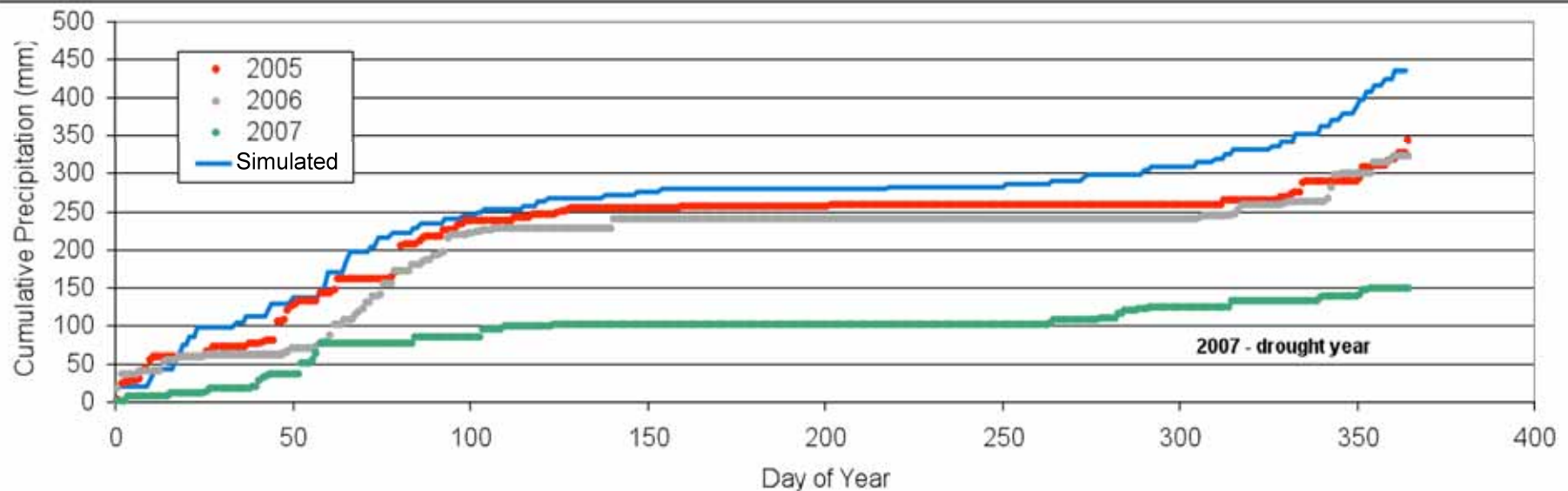
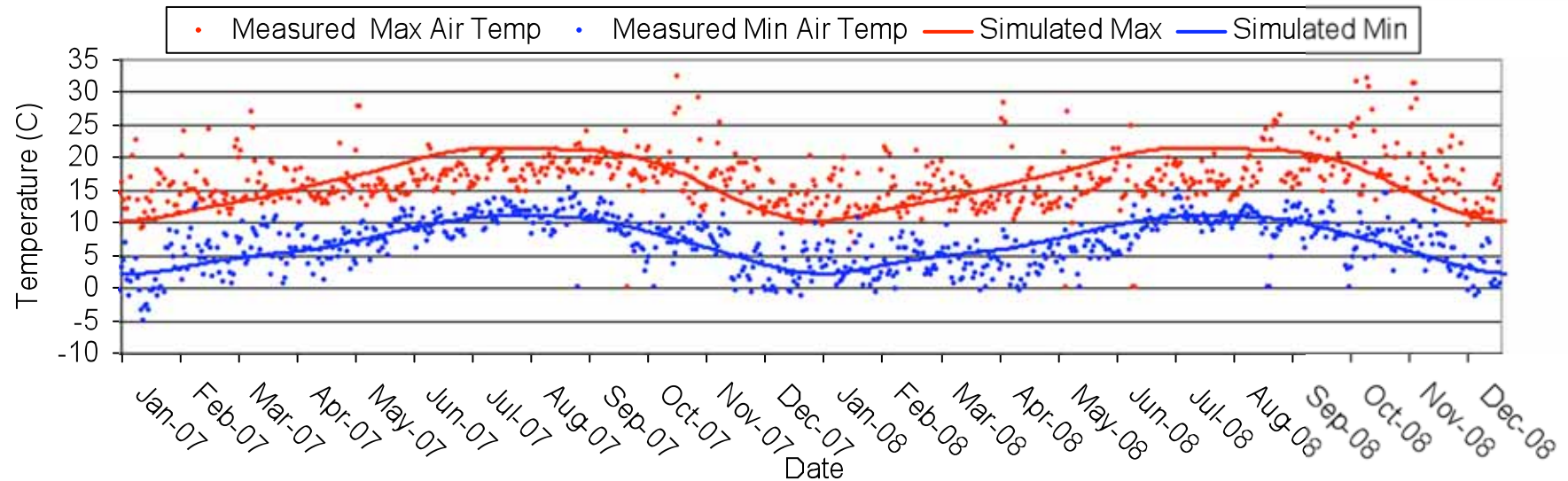
Model Comparisons:

- Air temperature/Precipitation Predictions
- Modeled Soil Temperature
- Modeled Soil Moisture
 - Need to modify model to allow input of actual meteorological data
- Surface CH₄ Emission Comparison

Air Temperature/Precipitation Simulation

Monterey, CA – Marina Landfill

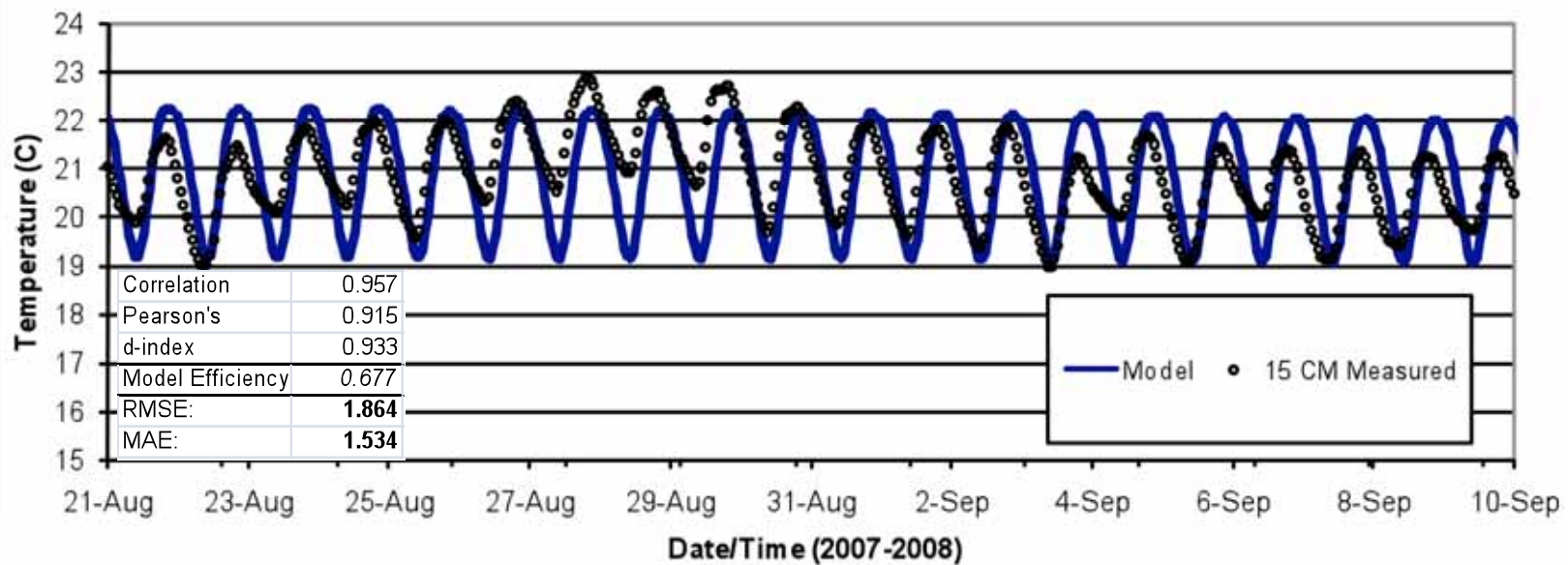
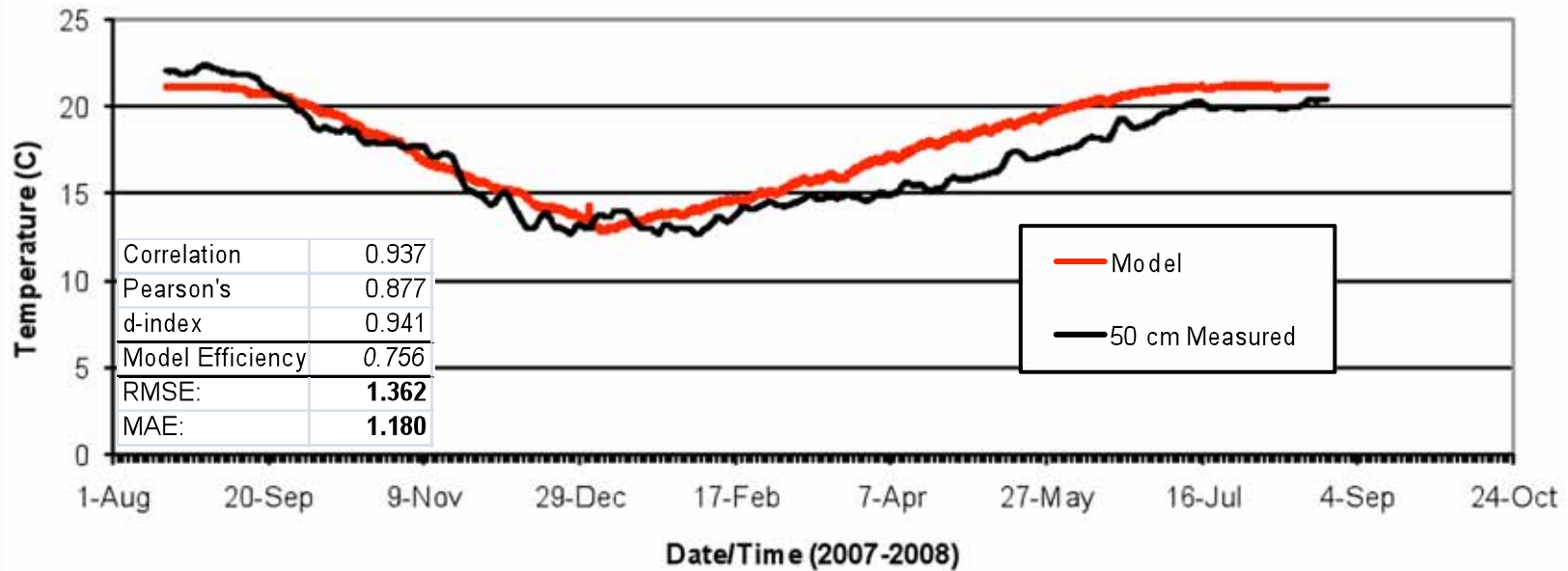
d-index	0.922
Model Efficiency	0.619
RMSE:	0.478
MAE:	1.835



Precipitation data from : Weather Underground (wunderground.com)

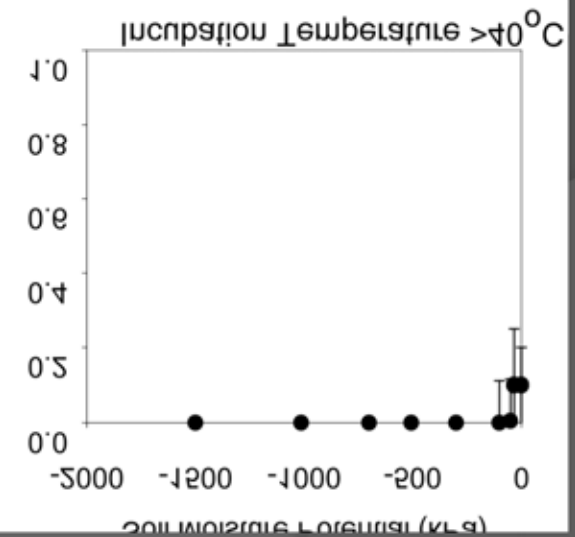
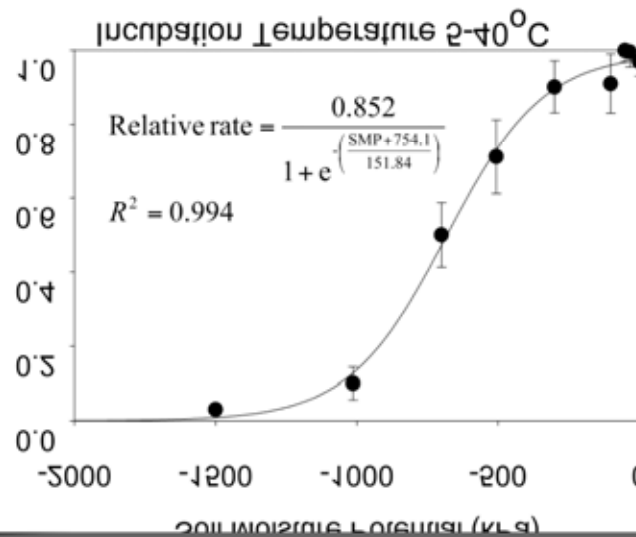
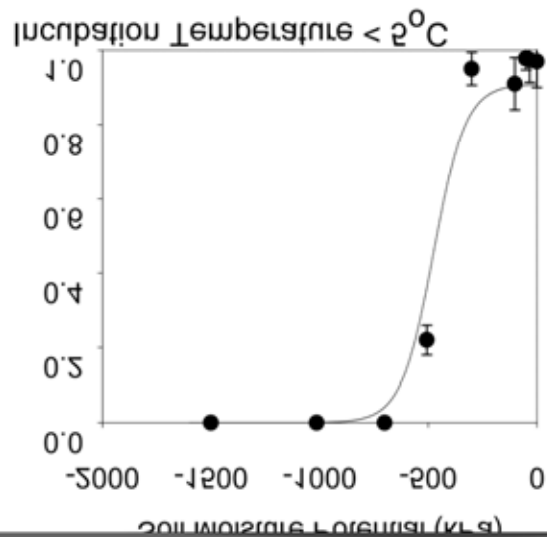
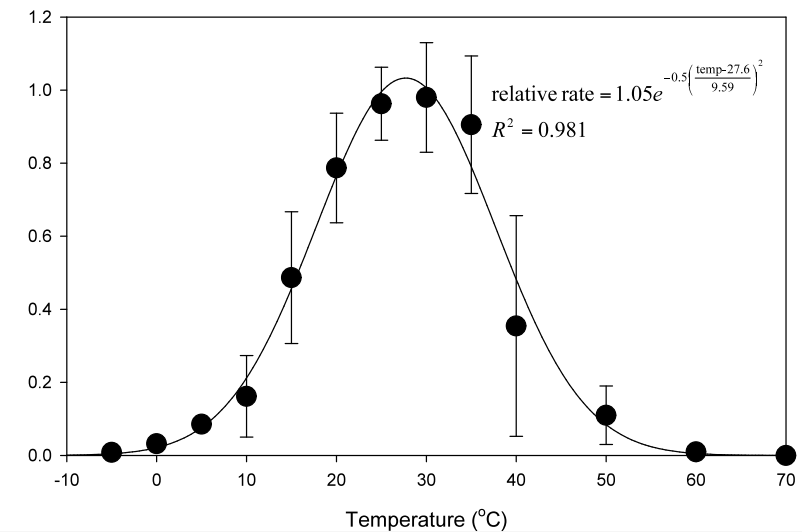
Marina Landfill Comparison

15 cm (intermediate cover) and 50 cm depth (final cover)



Laboratory Studies for Methane Oxidation Modeling

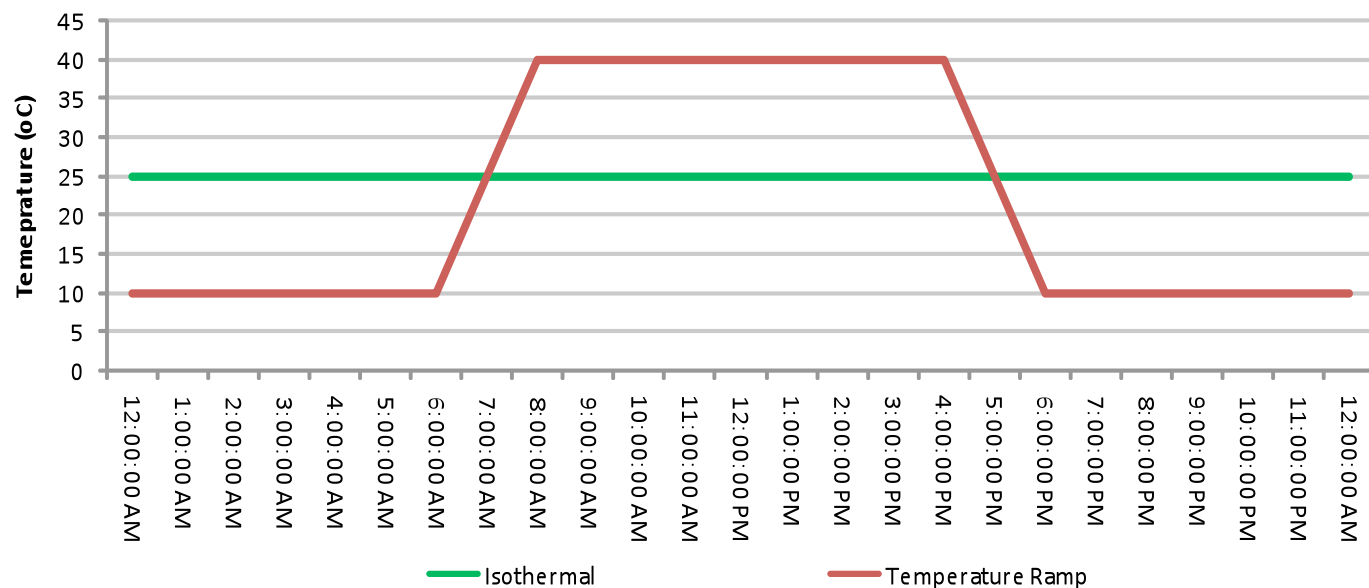
- A total of 2,112 soil incubations have been completed using Marina and Scholl Canyon cover soils
- Temperature range of 0-70 °C and moisture range from -15 bar to zero (saturated) soil moisture potential
- Isothermal and simulated diurnal fluctuations



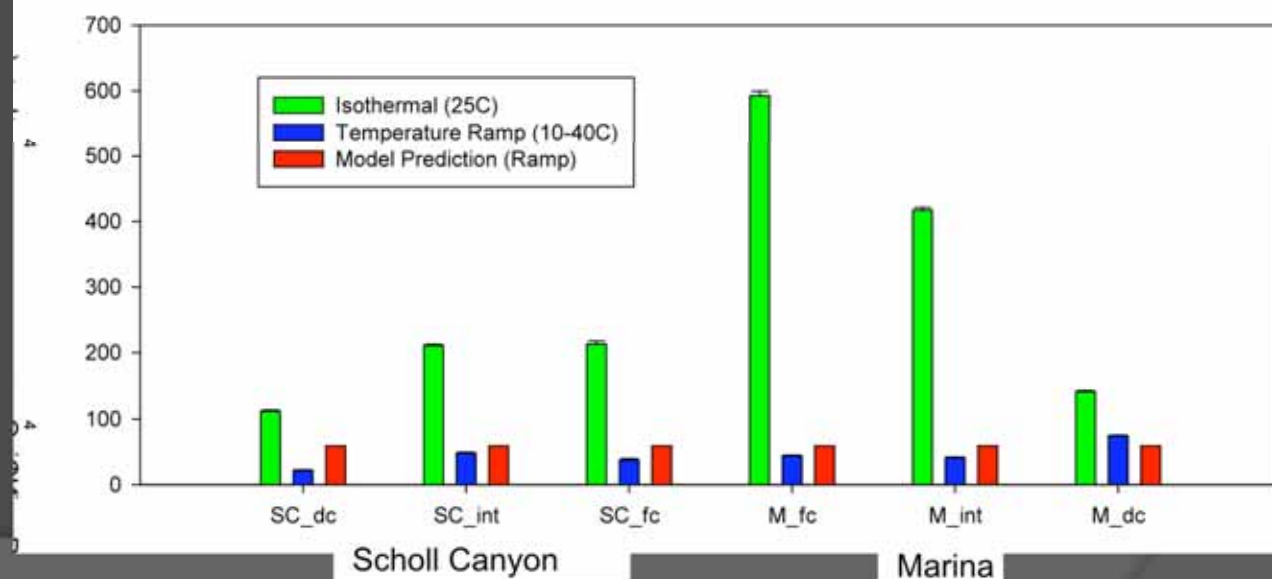
• The soil moisture potential for 50% of the oxidation activity for the two validation sites ~ -600 kPa; Threshold = -1200 kPa

Impact of Diurnal Temperature Fluctuations

Same average
daily temperature
(25 °C)

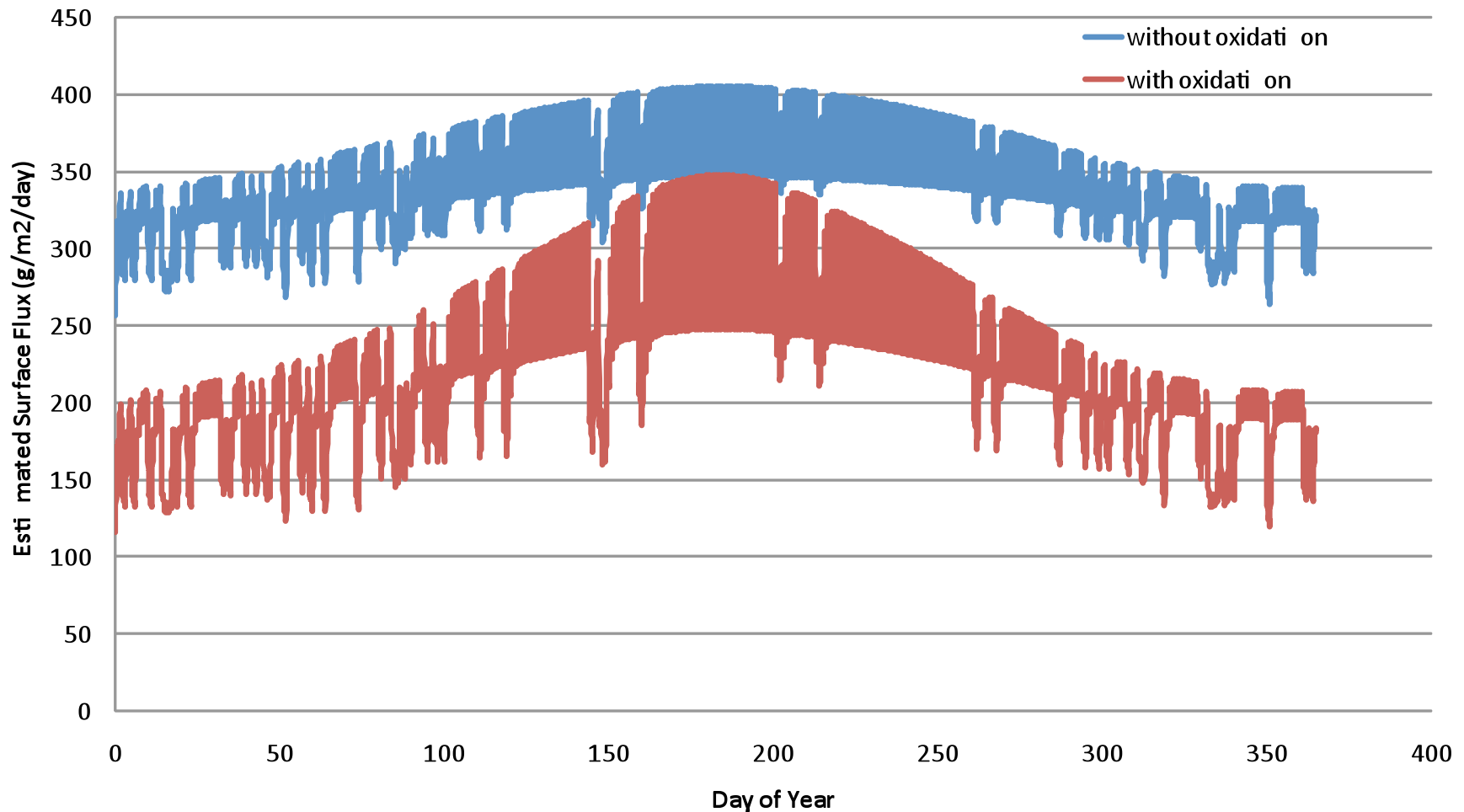


However – differences
observed in net
oxidation rates



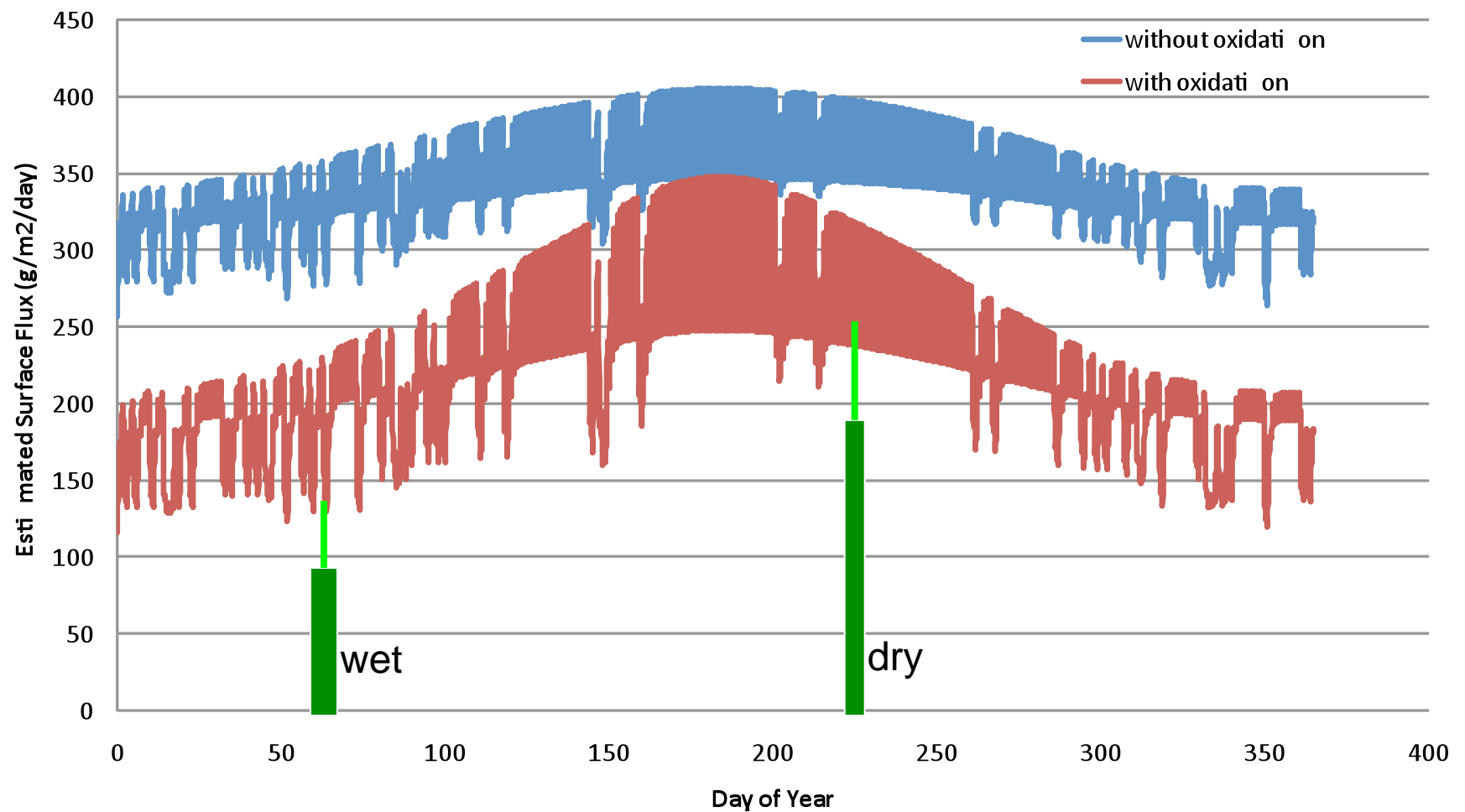
Model Results: Surface Emissions

Marina Intermediate Cover – with and without methane oxidation
30 cm (12" thick) Sandy Clay Loam

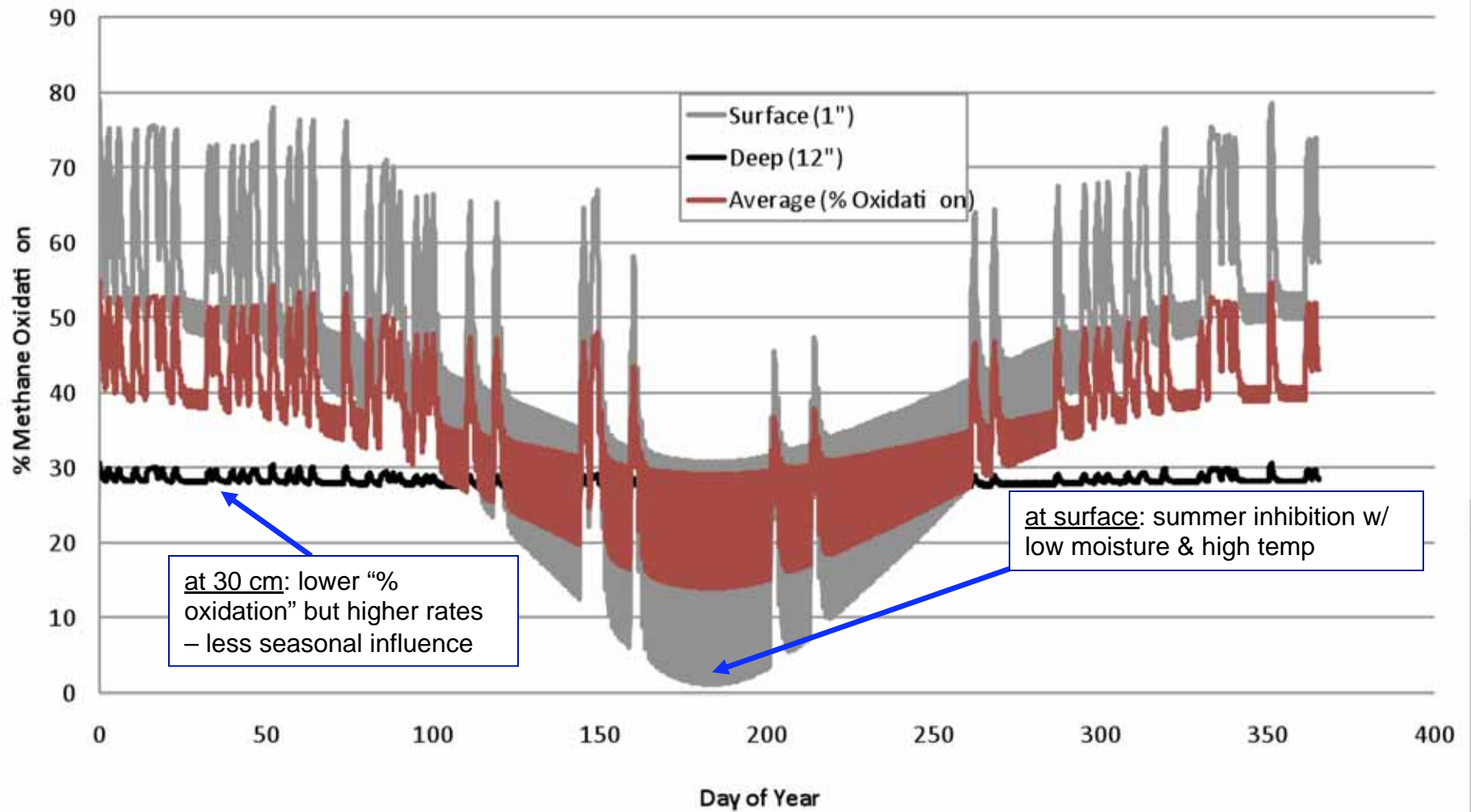


Model Results: Surface Emissions

Comparison to field data



Looking at % Methane Oxidation:

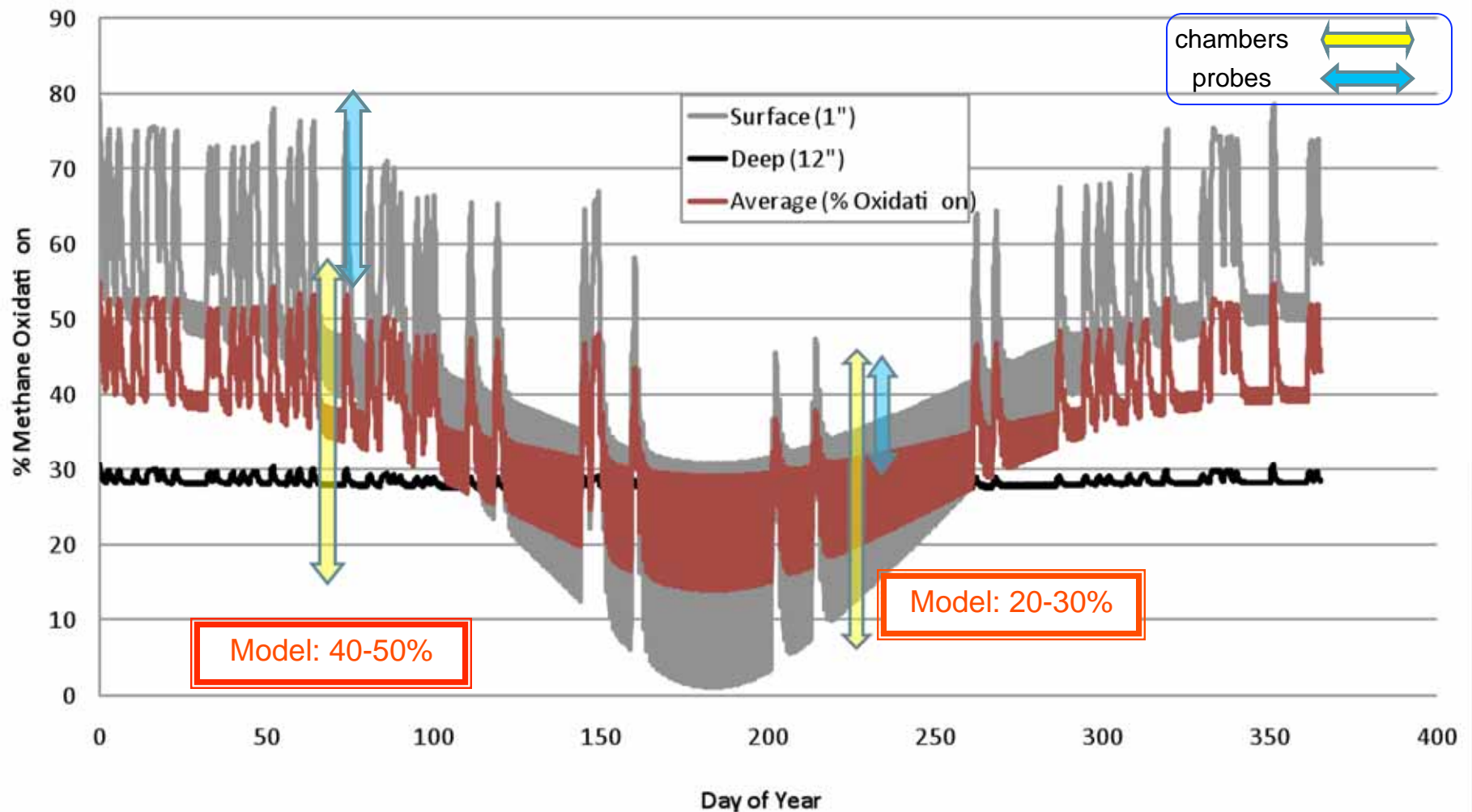


Comparison to Field Data:

Isotopic Analyses → Avg. CH₄ Oxidation Estimation

March (wet) Flux Chambers 10-53% Probes: 50-74%

August (dry) Flux Chambers 2-43% Probes: 25-40%



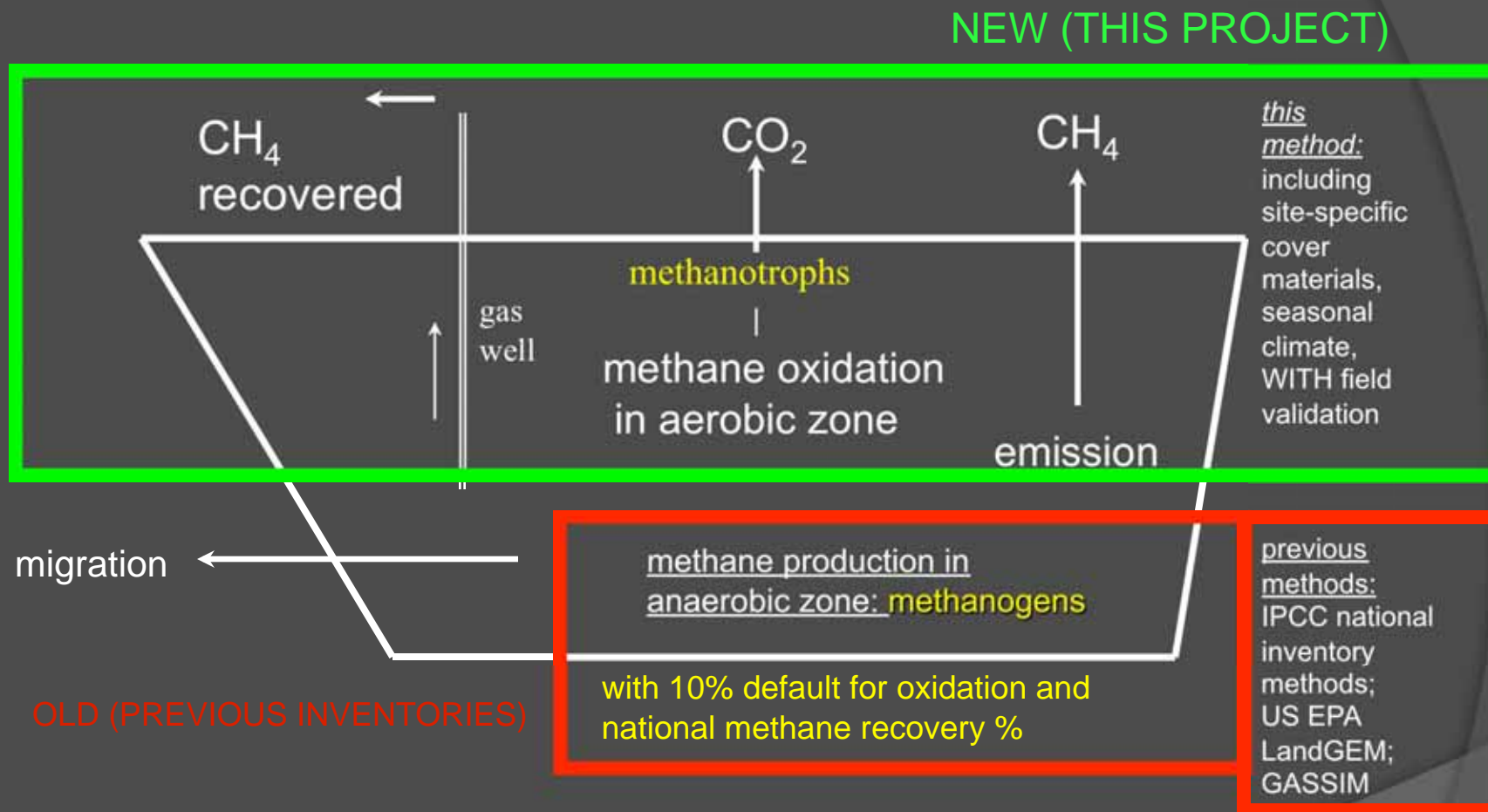
Summary and Conclusions:

Project is developing a new GHG Inventory Methodology for landfill methane focusing on the fate and transport of methane through the cover soils.

Based on:

- Expansion and integration of existing field-validated modeling approaches for meteorology and soil microclimate, including use of publicly-available climatic databases
- Site specific data for cover soils and areas with gas recovery
- Modeling for methane emissions inclusive of seasonal methane oxidation in cover soils
- Model Validation:
 - Field validation over 2 annual cycles
 - Supporting laboratory incubation studies for methane oxidation
- Model is currently undergoing Beta testing... should be finalized early 2010

Summary and Conclusions:



“The difficulty lies, not in the new ideas, but in escaping the old ones...”

-John Maynard Keynes

Acknowledgments: CEC, CIWMB, ARB



Special thanks to the field sampling crew:

Chad Rollofson, Martin duSaire, and Dean Peterson

Field Validation Sites:

Scholl Canyon Landfill (Los Angeles County Sanitation Districts)

Marina Landfill (Monterey Bay Regional Waste Management Authority)

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